

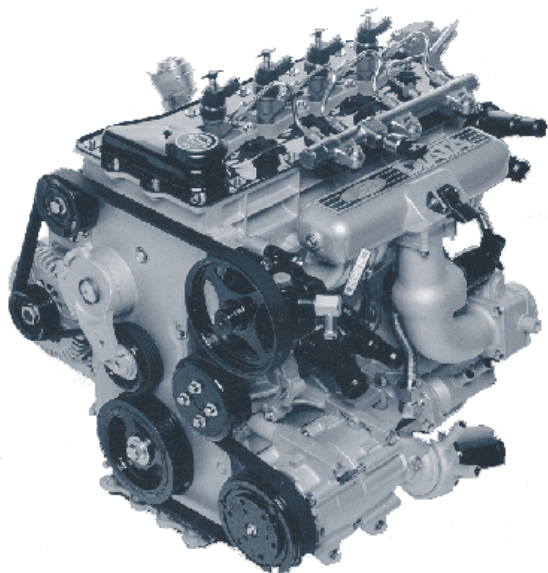
# OFFICE OF TRANSPORTATION TECHNOLOGIES

## *Hybrid Electric Vehicles - Power Unit Technologies*

Hybrid Electric Vehicles (HEVs) rely on power from both a heat engine and an electric motor to provide the torque to move the vehicle. In a hybrid vehicle, the heat engine, also called the hybrid power unit (HPU), performs different functions than its conventional counterpart. In a parallel hybrid vehicle, the HPU drives the wheels through a transaxle; in a series hybrid vehicle, it drives an alternator to produce electricity. In the HEV, the electric motor assumes some of the power responsibilities of the HPU, thereby permitting the use of a smaller and more efficient engine. However, in order to achieve high fuel economy, the HEV configuration places additional demands on the HPU and requires more critical packaging and integration constraints. Specifically, the HPU must be able to start and stop much more quickly and the emissions during starts must be lower.

The HEV Program has conducted research and development on advanced heat engines and complete power unit technologies that will contribute to the Partnership for a New Generation of Vehicles (PNGV) goals for fuel efficiency and emission characteristics. The candidates for the HPU are the internal combustion engine and fuel cell, an attractive longer-term possibility. (The gas turbine and Stirling engines have also been investigated, but require further development beyond the PNGV timeframe). Fuel use in HPUs is an important variable, with reformulated gasoline, natural gas, alcohol, and other alternative fuels impacting both emissions and driving performance. The ability to achieve specific power and power density equal to or higher than that of conventional engines is also an important factor. Other considerations include noise and vibration reduction, reliability, durability, maintenance, operating costs, and safety.

## *CIDI Engines Are the Most Promising Hybrid Power Units for Meeting PNGV Goals*



*Ford Motor Company's prototype Direct Injection Aluminum Throughbolt Assembly (DIATA) engine has a target thermal efficiency that is considerably higher than achievable by comparably sized gasoline engines.*

A compression-ignition engine (diesel engine) achieves combustion through compression without use of a spark plug. It becomes a CIDI engine when it is enhanced with direct-injection, which is the high-pressure injection of the fuel directly into the combustion chamber. In comparison, a conventional diesel or spark-ignition engine mixes fuel and air in a pre-chamber. Throttle and heat losses, which occur as the fuel mixture travels from the pre-chamber into the combustion chamber, are averted in the CIDI, resulting in increased thermal efficiency. A critical innovation in CIDI fuel injection, called the high-pressure common-rail system, allows the decoupling of fuel injection pressure and timing from engine speed. CIDI engines have the highest thermal efficiency of any proven automotive power plant and are excellent propulsion system candidates for both conventional drive systems and hybrid configurations.

## *Emissions Are the Focus of Much Research*

Emission control technologies for spark-ignited (SI) engines are generally effective, but the current efficiency limitations of these engines are not conducive to achieving the fuel economy levels reflected in DOE and PNGV objectives. SI engine research has expanded from port fuel injection combustion research to include direct fuel injection in order to explore further improvements in efficiency and emissions reduction, with emphasis on lean-burn operation.

The conventionally fueled CIDI engine must reduce NO<sub>x</sub> (oxides of nitrogen) and particulate emissions to meet proposed Federal Tier 2 standards and California LEV II (Low Emissions Vehicle II) standards. As part of CIDI engine development work sponsored by DOE, alternative fuels, advanced in-cylinder combustion processes, and highly efficient after-treatment devices are being investigated on a collaborative basis between the U.S. auto industry and various Federal agencies. Key areas of CIDI research for NO<sub>x</sub> and particulate reduction include the following:

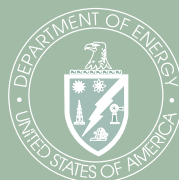
**Combustion system optimization.** Advanced fuel injection permits reduction in NO<sub>x</sub> and particulate formation during combustion. Engine controls and sensors can monitor the combustion process and exhaust gas composition to permit optimization of air-fuel ratio, exhaust gas recirculation, and the operation of engine after-treatment devices. One innovative research technique, developed at Sandia National Laboratory,

involved installation of a prototype CIDI engine with a quartz window and a laser diagnostic system to give researchers a look at how fuel mixes with air in the combustion chamber. Detailed observations provide insight into how fuel/air mixtures ignite, burn, and how NO<sub>x</sub> is formed. Results are contributing to the redesign of fuel injectors that will introduce less fuel into the cylinder under more controlled conditions.

**After-treatment.** Advanced catalyst systems that are efficient under lean-burn conditions are being developed. The potential of using plasma, or ionized gas, in conjunction with catalyst devices to treat lean-burn exhaust also is being researched. These devices may permit simultaneous reduction of NO<sub>x</sub> and particulates. Several Cooperative Research and Development Agreements (CRADAs) addressing exhaust aftertreatment, using NO<sub>x</sub> catalysts and non-thermal plasma technologies, are underway.

**Alternative and reformulated fuels.** Most after treatment devices for NO<sub>x</sub> and particulates are "poisoned" by the sulfur in diesel fuels. Work is required to determine the level of sulfur in reformulated fuels that can be tolerated in the after-treatment devices. Synthetic diesel from natural gas (Fischer Tropsch fuel) has no sulfur and has excellent characteristics as a CIDI fuel. Dimethyl ether (DME) also can be produced readily from natural gas and produces almost no particulates on combustion.

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